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(54) **Implantable medical device system**

(57) The invention relates to a solution with respect to implantable medical devices that are associated with telemetry means for wireless data exchange with external units. The invention involves selecting either an internal calculation processor (P_1) or an external calculation processor (P_2) for accomplishing a given data processing. In case the sum (E_1) of an estimated amount of energy (E_{1A}) to process the data in the internal calculation processor (P_1) and an estimated amount of energy (E_{1B}) required to then transmit an expected amount of result data to the external unit exceeds an estimated amount of energy (E_2) required to transmit the source data to the external unit, the external calculation processor (P_2) is selected. Otherwise, the internal calculation processor (P_1) is selected. The proposed method thereby achieves a minimal energy consumption in the implantable medical device. This, in turn, vouches for a device with a long battery life time and thus an improved patient comfort.

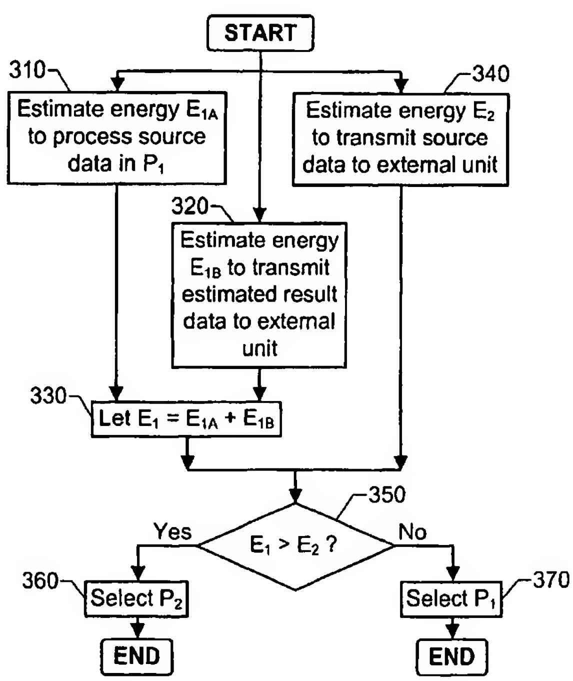

Fig. 3

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Description

THE BACKGROUND OF THE INVENTION AND PRIOR ART

[0001] The present invention relates generally to implantable medical devices that are associated with telemetry means for wireless data exchange with external units. More particularly the invention relates to a method in an implantable medical device system according to the preamble of claim 1, a computer program according to claim 6, a computer readable medium according to claim 7 and an implantable medical device system according to the preamble of claim 8.

[0002] Traditionally the data processing capacity in implantable medical devices has been relatively restricted, primarily due to limitations in the internal memory and processing capacity. However, the amount of processing in the devices has also been held low in order to economize the energy resources therein. Therefore, raw data has generally been transferred from the implantable device to an external unit for processing whenever a more extensive data analysis has been requested.

[0003] U.S. patent No. 5,603,331 discloses a data logging system for an implantable cardiac device with a capability of computing and storing histogram arrays of heart rate variability data over a prolonged period of time. A logarithmic data compression algorithm is used to save memory and energy resources in the cardiac device.

[0004] U.S. patent No. 6,161,043 describes another example of an implantable cardiac device having event recording capability with data compression. A compressed electrogram signal is here transmitted from the implantable device to an external programmer according to the following. First, an uncompressed starting value is sent. Nevertheless, following signal samples are sent in the form of delta signals in respect of the starting value. Finally, based on the delta signal, the programmer produces a decompressed signal, which may be presented graphically.

[0005] In recent years, however, the processing and data storage capacity of implantable medical devices has increased dramatically. Additionally, the battery technology has made many important advancements. Although the external data processing saves energy in the implantable medical device, the process of transferring the source data from the device to the external processing unit also consumes energy. In the light of today's comparatively competent processors it is therefore no longer self-evident that external processing is always preferable to internal ditto. In fact, transferring the raw data from the implantable medical device may very well demand more energy than performing the calculation in the device and instead transmit the result data for external presentation or further processing.

SUMMARY OF THE INVENTION

[0006] It is therefore an object of the present invention to address this problem and thus provide an improved solution in an implantable medical device system.

[0007] According to one aspect of the invention this object is achieved by a method in an implantable medical device system as described initially, which is characterized by selecting the location for performing a processing between the first calculation processor and the second calculation processor, where the selecting is based on a selection algorithm.

[0008] An important advantage attained by this strategy is that the location for any relatively demanding data processing operation may be selected such that a minimal amount of energy resources is used in the implantable medical device. This, in turn, vouches for a device with a long battery life time and thus an improved patient comfort.

[0009] According to a preferred embodiment of this aspect of the invention, the selection algorithm involves consideration of a first estimated energy amount for performing the processing in the first calculation processor plus transmitting an expected amount of result data over a channel between the first wireless interface and the second wireless interface. The algorithm also involves consideration of a second estimated energy amount for instead transmitting the source data over the channel. Finally, a comparison is made between the first estimated energy amount and the second estimated energy amount. The smallest amount of energy then determines the location for performing the processing, such that the location is selected which results in the lowest energy consumption in the implantable medical device.

[0010] According to another preferred embodiment of this aspect of the invention, the selection algorithm takes into account an estimated required amount of processing to generate the result data. An advantage attained by considering this parameter is that a threshold may be set, such that all processing tasks below a certain complexity (or amount) is always processed internally. Thus, these operations will not be subject to any evaluation as to the location of the processing. This, in turn, saves energy in the implantable medical device. In any case, an estimation of the expected amount of processing to be performed provides an important basis for the decision algorithm.

[0011] According to yet another preferred embodiment of this aspect of the invention, the selection algorithm takes into account a current capacity of a channel between the first wireless interface and the second wireless interface. It is advantageous to consider this parameter, since due to variations in the radio environment, the channel's quality may vary from excellent to extremely poor. In the former case, transmitting the source data for external processing may be preferable (i.e. in the second calculation processor), whereas in the latter case, internal processing (i.e. in the first calcula-

tion processor) will typically be preferable. A low quality channel is namely inclined to require a comparatively large number of re-transmissions and consequently be both time and energy consuming.

[0012] According to still another preferred embodiment of this aspect of the invention, the selection algorithm takes into account an amount of overhead data required to transmit the source data and/or an estimated amount of result data over a channel between the first wireless interface and the second wireless interface. It is desirable to consider the overhead data when selecting the location for performing a certain data processing, since it is the total amount of data, which must be transmitted that determines the most advantageous location. Moreover, due to the nature of the data (i.e. whether is represents source data or result data), different overhead data may be demanded. Furthermore, the amount of overhead data may be due to the channel quality.

[0013] According to another aspect of the invention this object is achieved by a computer program directly loadable into the internal memory of a digital computer, comprising software for controlling the method described above when said program is run on a computer.

[0014] According to yet another aspect of the invention this object is achieved by a computer readable medium, having a program recorded thereon, where the program is to make a computer perform the method described above.

[0015] According to still another aspect of the invention this object is achieved by an implantable medical device system as described initially, which is characterized in that at least one of the implantable medical device and the external unit includes a selector, which is adapted to select the location for performing a processing between the first calculation processor and the second calculation processor. The selector operates according to a selection algorithm. This design is advantageous, since it allows selection of the location for a data processing operation, such that a minimal amount of energy resources is used in the implantable medical device. This, in turn, vouches for a device with a long battery life time and thus an improved patient comfort.

[0016] According to a preferred embodiment of this aspect of the invention, the external unit contains a programmer unit, which is adapted to read information from the implantable medical device and update the contents of one or more digital storages therein. A typical situation when resource demanding data processing may be required is when a physician examines whether a particular device has parameter settings which are optimal with respect to the patient into which the device is implanted. In these situations, the physician utilizes a programmer. Therefore, it is advantageous to combine the programmer function with the proposed external processing option.

[0017] According to another preferred embodiment of this aspect of the invention, the external unit instead includes a repeater station, which is adapted to communicate with a particular implantable medical device and at least one remote surveillance and/or programming unit. Irrespective of whether the repeater station is mobile or stationary, it may take over any more demanding data processing tasks that are placed on the implantable medical device whenever this device is located within a communication range of the repeater station. Again, this increases the chances of obtaining a device with a prolonged battery life time.

[0018] Although the proposed solution is primarily intended for cardiac devices, such as pacemakers and defibrillators, the invention is equally well applicable to any alternative type of implantable medical devices, for example drug pumps or neurostimulators.

BRIEF DESCRIPTION OF THE DRAWINGS

[0019] The present invention is now to be explained more closely by means of preferred embodiments, which are disclosed as examples, and with reference to the attached drawings.

Figure 1 shows an implantable medical device system according to an embodiment of the invention,

Figure 2 illustrates, by means of a flow diagram, the general working principle according to the invention, and

Figure 3 illustrates, by means of a flow diagram, a method of selecting a calculation processor for a data processing task according to an embodiment of the invention.

DESCRIPTION OF PREFERRED EMBODIMENTS OF THE INVENTION

[0020] Figure 1 shows an implantable medical device system according to an embodiment of the invention. The system includes an implantable medical device 110 and an external unit 120, which may communicate with each other via a channel C. For example, the implantable medical device 110 receives program code P_C from the external unit 120 and transmits various kinds of measurement data D_S, D_R in the opposite direction.

[0021] In addition to, for instance a cardiac pacemaker, the implantable medical device 110 contains a first wireless interface I_1, a first calculation processor P_1, a first selector S_1 and a digital storage M_1. The external unit 120 contains a second wireless interface I_2, a second calculation processor P_2, a second selector S_2 and a data presentation interface I_P. The channel C is set up between the first wireless interface I_1 and the second wireless interface I_2, for example as a bi-directional radio link. Thereby, the digital storage M_1 may be updated with program code P_c and/or parameter settings pertaining to the device's 110 mode of operation may be re-

ceived. According to preferred embodiment of the invention, the external unit 120 namely includes a programmer unit or a repeater station.

[0022] When the channel C has been established and the device 110 comes across a data processing task of at least a certain complexity (or amount), a decision is taken whether the processing shall be carried out either by the first calculation processor P_1 (in the device 110) or the second calculation processor P_2 (in the external unit 120). This decision may be taken by the first selector S_1 or by the second selector S_2. According to a preferred embodiment of the invention, however, the second selector S_2 in the external unit 120 effects the decision in order to save energy in the implantable medical device 110. Nevertheless, in most cases the device 110 will trigger the decision process.

[0023] Irrespective of whether the decision implies that the processing should be performed by the first calculation processor P_1 and therefore result data D_R will be transmitted to the external unit 120 after completed processing, or the decision implies that the processing should be performed by the second calculation processor P_2 and consequently unprocessed source data D_S will be transmitted to the external unit 120 instead, the result data D_R (or a parameter derived there from) is preferably presented on a user-friendly format via the data presentation interface Ip. In any case, the selectors S_1 and S_2 operate according to a selection algorithm, which will be described below with reference to the figure 2 and 3.

[0024] Figure 2 illustrates, by means of a flow diagram, the general working principle according to the invention. A first step 210, identifies a processing to be performed, which is subject to a decision as to a selection between an internal or an external processor. Typically, a choice of calculating processor only arises if a channel C has already been established between the implantable medical device in question and at least one external unit. Moreover, the amount or complexity of the data processing should preferably exceed a predetermined threshold value. A following step 220 investigates, based on a selection algorithm, whether an internal processor P_1 or an external processor P_2 should be used. In the former case, a step 230 processes the source data into corresponding result data whereafter a step 240 transmits the result data via the channel C to the external unit. Otherwise, a step 260 transmits the source data to the external unit via the channel C. Subsequently, a step 270 processes the source data into corresponding result data. After the steps 240 and 270 respectively, a step 250 presents the result data in the external unit, preferably on a graphical format and by means of a data presentation interface adapted therefor.

[0025] According to a preferred embodiment of the invention, the selection algorithm on which the selection in the step 220 is based, takes into account one or more of the following parameters: an estimated amount of processing required to generate the result data, a current capacity of the channel between the implantable medical device and the external unit (i.e. between the first wireless interface I_1 and the second wireless interface I_2 in figure 1) and an amount of overhead data required to transmit the source data and/or the result data over this channel. The selection algorithm namely aims at, for a given (estimated) amount of result data, minimizing the energy consumption in the implantable medical device per data bit in the result data.

[0026] In general, an acceptably low bit error rate (BER) for the data transmission is desired. This may be accomplished by a variation of the output power, the channel bandwidth and/or the degree of forward error correction (FEC) coding. In most cases, the bandwidth is determined by a standardized protocol according to which the wireless interfaces I_1 and I_2 operate and/or the type of modulation which these interfaces can handle. Likewise, the possibilities to vary the FEC-coding is normally rather restricted. Consequently, varying the output power will, as a rule, be the most important means to obtain an acceptable BER.

[0027] In order to sum up, the general method for selecting a calculation processor for a data processing task according to an embodiment of the invention will now be described with reference to figure 3.

[0028] A first step 310 estimates a first amount of energy E_{1A} required to process a given set of source data into corresponding result data in the first calculation processor P_1 (i.e. in the implantable medical device). Another step 320, estimates a second amount of energy E_{1B} required to transmit an expected amount of result data to the external unit. As mentioned earlier, this estimation may take into consideration a current capacity and quality of the channel between the implantable medical device and the external unit and the amount of overhead data required. Yet another step 340 estimates a second decision energy E_2 required to transmit the given set of source data to the external unit. Preferably, however not necessarily, two or more of the steps 310, 320 and 340 are executed in parallel.

[0029] A step 330 adds the first amount of energy E_{1A} to the second amount of energy E_{1B} to obtain a first decision energy E_1. After that, a step 350 compares the first decision energy E_1 with the second decision energy E_2, and depending on which is larger, a step 360 or a step 370 selects external processing (i.e. in P_2) or internal processing (i.e. in P_1) respectively. If the first decision energy E_1 is larger than the second decision energy E_2, external processing is selected. Otherwise, internal processing is selected.

[0030] All of the process steps, as well as any subsequence of steps, described with reference to the figure 3 above may be controlled by means of a computer program being directly loadable into the internal memory of a computer, which includes appropriate software for controlling the necessary steps when the program is run on a computer. Furthermore, such computer program can be recorded onto arbitrary kind of computer

readable medium as well as be transmitted over arbitrary type of network and transmission medium.

[0031] The term "comprises/comprising" when used in this specification is taken to specify the presence of stated features, integers, steps or components. However, the term does not preclude the presence or addition of one or more additional features, integers, steps or components or groups thereof.

[0032] The invention is not restricted to the described embodiments in the figures, but may be varied freely within the scope of the claims.

Claims

1. A method in an implantable medical device system, comprising an implantable medical device (110) in turn including a first calculation processor (P_1) and a first wireless interface (I_1) for exchanging data (D_S, D_R; P_C) with other units, and an external unit (120) including a second calculation processor (P_2) and a second wireless interface (I_1) for exchanging data (P_C; D_S, D_R) with at least one implantable medical device (110), the method involving

   processing of source data (D_S) into result data (D_R), and

   presenting the result data (D_R) in the external unit (120),

   characterized by

   selecting either the first calculation processor (P_1) or the second calculation processor (P_2) for performing a processing, the selecting being based on a selection algorithm.

2. A method according to claim 1, **characterized by** the selection algorithm involving

   a consideration of a first estimated energy amount (E_1) for performing the processing in the first calculation processor (P_1) and transmitting a result data (D_R) of an estimated size over a channel (C) between the first wireless interface (I_1) and the second wireless interface (I_2),

   a consideration of a second estimated energy amount (E_2) for transmitting the source data (D_S) over the channel (C), and

   a comparison between the first estimated energy amount (E_1) and the second estimated energy amount (E_2), the smallest of which determines the location for performing the processing.

3. A method according to any one of the preceding claims, **characterized by** the selection algorithm taking into account an estimated amount of processing required to generate the result data (D_R).

4. A method according to any one of the preceding claims, **characterized by** the selection algorithm taking into account a current capacity of a channel (C) between the first wireless interface (I_1) and the second wireless interface (I_2).

5. A method according to any one of the preceding claims, **characterized by** the selection algorithm taking into account an amount of overhead data required to transmit at least one of the source data (D_S) and the result data (D_R) over a channel (C) between the first wireless interface (I_1) and the second wireless interface (I_2).

6. A computer program directly loadable into the internal memory of a digital computer, comprising software for performing the steps of any of the claims 1 - 5 when said program is run on a computer.

7. A computer readable medium, having a program recorded thereon, where the program is to make a computer perform the steps of any of the claims 1 - 5.

8. An implantable medical device system, comprising:

   an implantable medical device (110) including a first calculation processor (P_1) adapted to process source data (D_S) into result data (D_R) and a first wireless interface (I_1) adapted to exchange data (D_S, D_R; P_C) with other units, and an external unit (120) including a second calculation processor (P_2) adapted to process source data into result data (D_R), a second wireless interface (I_2) adapted to exchange data (P_C; D_S, D_R) with at least one implantable medical device (110), and a data presentation interface (I_P) adapted to present the result data (D_R), **characterized in that**

   at least one of the implantable medical device (110) and the external unit (120) comprises a selector (S_1; S_2) adapted to select the first calculation processor (P_1) or the second calculation processor (P_2) for performing a processing, the selector (S_1; S_2) operating according to a selection algorithm.

9. A system according to claim 8, **characterized in that** the external unit (120) comprises a programmer unit adapted to read information from the implantable medical device (110) and update the contents (P_C) of at least one digital storage (M_1) therein.

10. A system according to claim 8, **characterized in that** the external unit (120) comprises a repeater station adapted to communicate with a particular implantable medical device (110).

11. A system according to any one of the claims 8 - 10, **characterized in that** the implantable medical de-

vice (110) comprises a cardiac pacemaker.

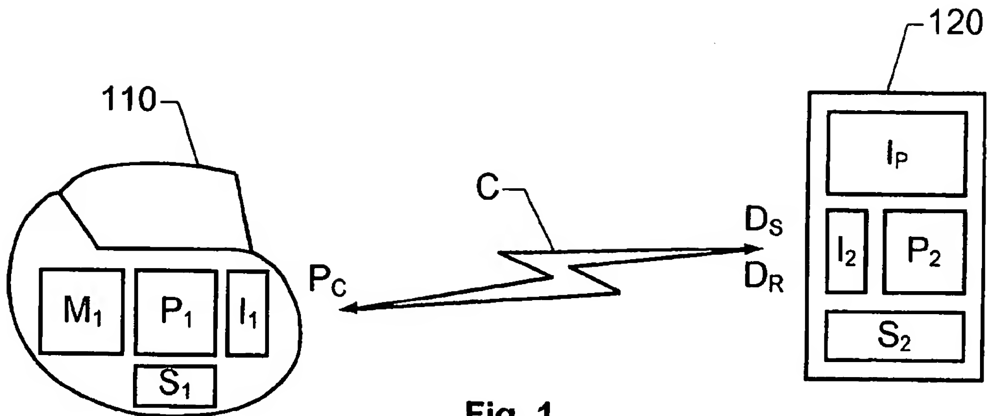
120
110
C
Ds
DR
Pc
IP
I2
P2
S2
M1
P1
I1
S1

Fig. 1

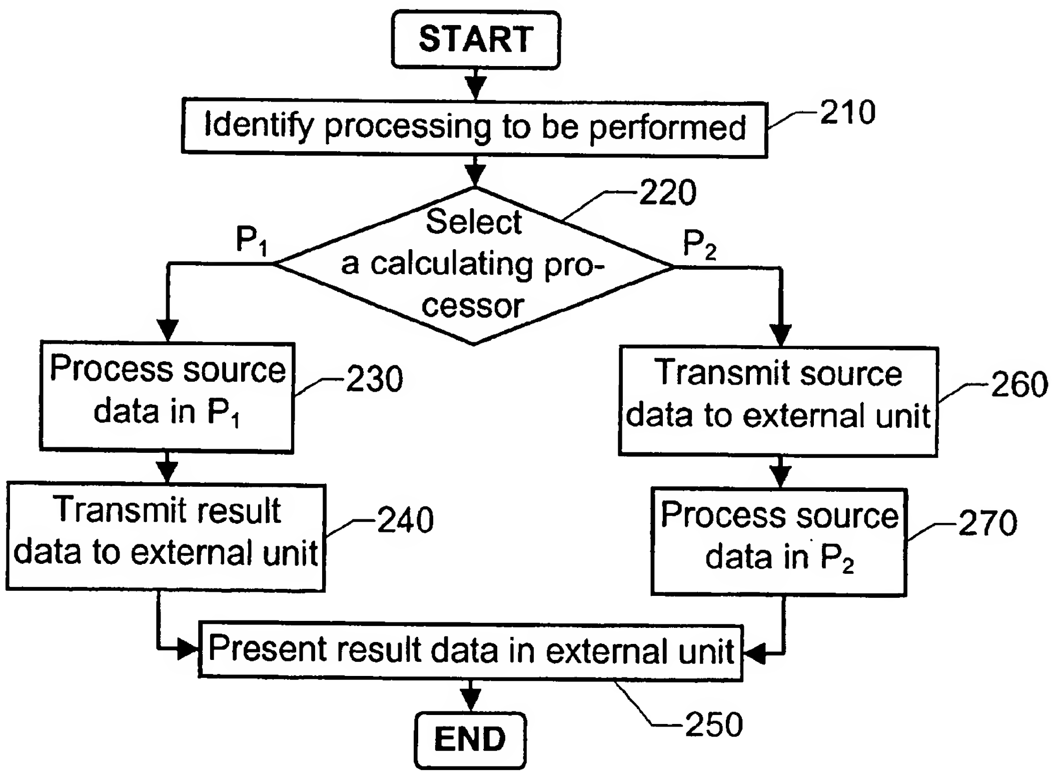
START
Identify processing to be performed
210
220
Select a calculating processor
P1
P2
Process source data in P1
230
Transmit source data to external unit
260
Transmit result data to external unit
240
Process source data in P2
270
Present result data in external unit
END
250

Fig. 2

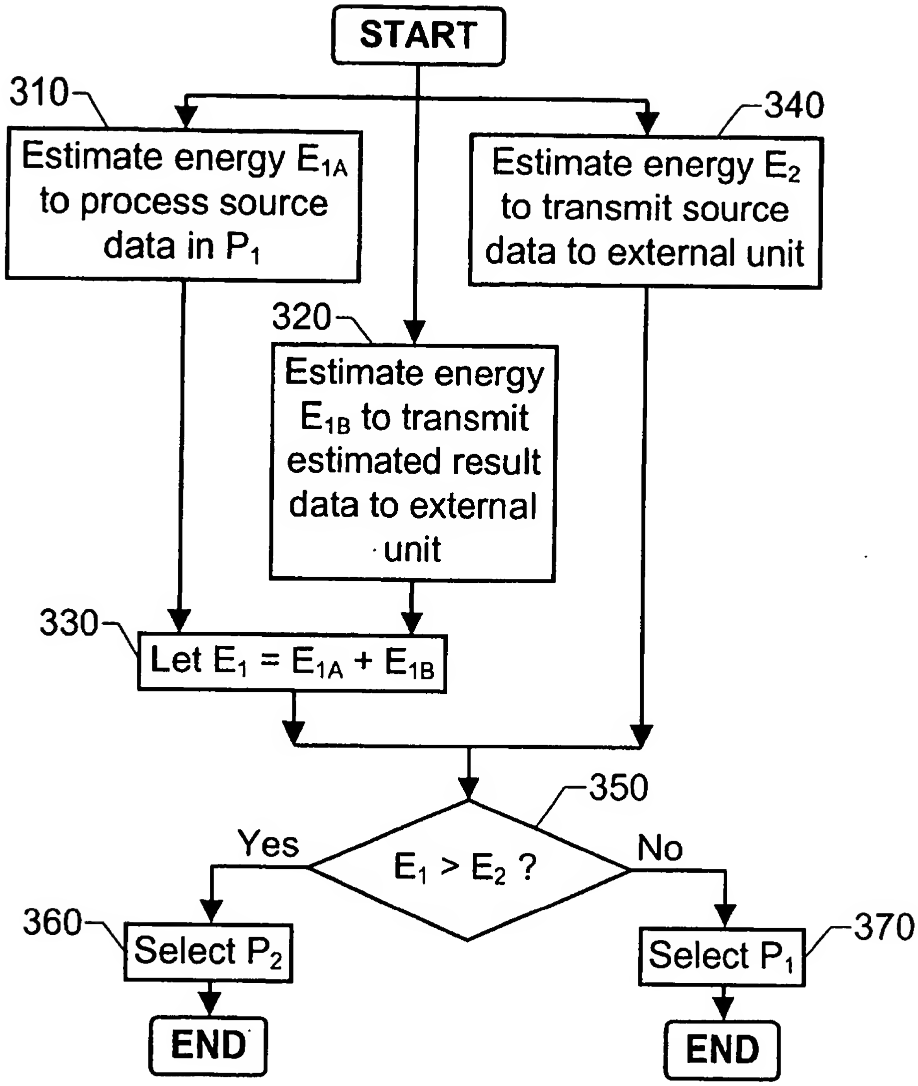
START
310
Estimate energy E1A to process source data in P1
340
Estimate energy E2 to transmit source data to external unit
320
Estimate energy E1B to transmit estimated result data to external unit
330
Let E1 = E1A + E1B
350
E1 > E2 ?
Yes
No
360
Select P2
370
Select P1
END
END

Fig. 3

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